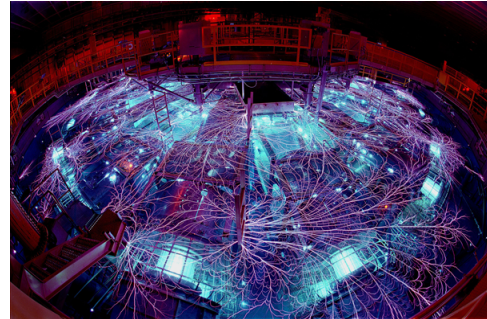


Fundamental Science with Pulsed Power: Research Opportunities and User Meeting

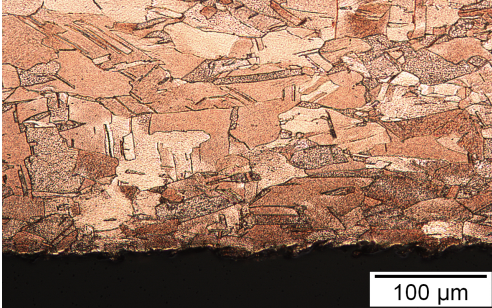
SAND 2014-

Hotel Andaluz
Albuquerque, NM
July 20 – 23, 2014

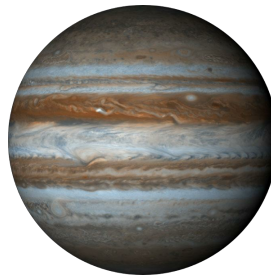
Thomas R. Mattsson
Alan Wootton
Daniel B. Sinars
Dylan Spaulding
Don Winget



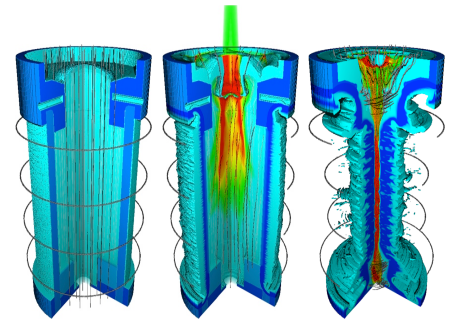
Sandia's Z machine



Material Science



Planetary
Science



MagLIF



U.S. DEPARTMENT OF
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Summary of workshop

The fifth Fundamental Science with Pulsed Power: Research Opportunities and User Meeting was held in Albuquerque, NM, July 20-23, 2014. The purpose of the workshop was to bring together leading scientists in four research areas with active fundamental science research at Sandia's Z facility: Magnetized Liner Inertial Fusion (MagLIF), Planetary Science, Astrophysics, and Material Science.

The workshop was focused on discussing opportunities for high-impact research using Sandia's Z machine, a future 100 GPa class facility, and possible topics for growing the academic (off-Z-campus) science relevant to the Z Fundamental Science Program (ZFSP) and related projects in astrophysics, planetary science, MagLIF-relevant magnetized HED science, and materials science. The user meeting was for Z collaborative users to: a) hear about the Z accelerator facility status and plans, b) present the status of their research, and c) be provided with a venue to meet and work as groups.

Following presentations by Mark Herrmann and Joel Lash on the fundamental science program on Z and the status of the Z facility where plenary sessions for the four research areas. The third day of the workshop was devoted to breakout sessions in the four research areas. The plenary- and breakout sessions were for the four areas organized by Dan Sinars (MagLIF), Dylan Spaulding (Planetary Science), Don Winget and Jim Bailey (Astrophysics), and Thomas Mattsson (Material Science). Concluding the workshop were an outbrief session where the leads presented a summary of the discussions in each working group to the full workshop. A summary of discussions and conclusions from each of the research areas follows and the outbrief slides are included as appendices.

Invitation

Colleagues,

The fifth Fundamental Science with Pulsed Power: Research Opportunities and User Meeting will be held at Hotel Andaluz, Albuquerque, NM, July 20 (evening) through July 23 (all day) 2014.

We are very excited to invite participation to the 2014 workshop and user meeting, as it will capture the broad range of research at the Z-facility at Sandia National Laboratories.

The workshop website is now online, including web registration (\$150 fee) and hotel information, importantly, the room block is being held until July 11.
<http://www.sandia.gov/pulsedpower/meeting.html>

The workshop will focus on discussing opportunities for high-impact research using Sandia's Z machine, a future 100 GPa class facility, and possible topics for growing the academic (off-Z-campus) science relevant to the Z Fundamental Science Program (ZFSP) and related projects in astrophysics, planetary science, MagLIF-relevant magnetized HED science, and materials science. The user meeting is for Z collaborative users to: a) hear about the Z accelerator facility status and plans, b) present the status of their research, and c) be provided with a venue to meet and work as groups. Please see the draft agenda below.

Invited speakers include

Professor Yogi Gupta, Washington State University.

Professor Stein Jacobsen, Harvard University.

Professor Yue Ying Lau, University of Michigan.

Professor Kanani Lee, Yale University.

Professor Anil Pradhan, The Ohio State University.

Professor Ronald Redmer, Rostock University, Rostock, Germany.

Professor Charles Seyler, Cornell University.

Dr. Dylan Spaulding, Harvard University.

Professor Renata Wentzcovitch, University of Minnesota.

Professor Don Winget, University of Texas at Austin.

Dr. Jim Bailey, Sandia National Laboratories.

Dr. Sebastien Hamel, Lawrence Livermore National Laboratory.

Dr. Marcus Knudson, Sandia National Laboratories.

Dr. Thomas Mattsson, Sandia National Laboratories.

Dr. Russ Olson, Los Alamos National Laboratory.

Dr. David Reisman, Sandia National Laboratories.

Dr. Bruce Remington, Lawrence Livermore National Laboratory.

Dr. Daniel Sinars, Sandia National Laboratories.

Agenda

ZFSP2014 Agenda
July 20 – 23, 2014
Hotel Andaluz, Albuquerque, NM

Sunday July 20, 2014		
6:00 – 8:00 pm	Registration, PI meeting, and reception	Thomas Mattsson
Monday July 21, 2014		Speaker
7:30 – 8:30	Breakfast	Breakfast
8:30 – 8:45	Welcome and introductions	Thomas Mattsson
8:45 – 9:15	HED Science at Sandia and the ZFSP	Mark Herrmann
9:15 – 9:45	Z-facilities status and outlook	Joel Lash
9:45 – 10:15	Break	Break
10:15 – 11:00	MagLIF research at Sandia	Dan Sinars
11:00 – 11:30	Effects of thermal transport and laser beam smoothing on beam propagation through long-scale-length plasmas	Dustin Froula
11:30 – 1:00	Lunch	Lunch
1:00 – 1:30	XMHD simulation of dense z-pinches with examples from radial foils, cylindrical foils, and gas puff z-pinches	Charles Seyler
1:30 – 2:00	Experimental Exploration of Dynamic, Astrophysically-relevant MHD Plasmas	Paul Bellan
2:00 – 2:30	Some contemporary issues on magneto-RT instability	Y Y Lau
2:30 – 3:00	MagLIF Research at the LLE	Jonathan Davies
3:15 – 3:20	Welcome/setup	Thomas Mattsson
3:20 – 4:00	Dynamic Response of Solids using Planar Loading: Scientific Questions and Future	Yogi Gupta
4:00 – 4:30	Directions Thor: Development of a megabar-class pulsed power accelerator	David Reisman
4:30 – 5:00	Microstructural Influences on Dynamic Material Strength	Russ Olson
5:00 – 5:30	Probing novel regimes of HED science: plastic flow, lattice dynamics, and collisionless shocks	Bruce Remington

Tuesday July 22, 2014		Organizer
Note 3 breakout rooms available for those not attending plenary sessions		
7:30 – 8:30	Breakfast	Breakfast
8:30 – 8:45	Welcome/setup	Dylan Spaulding & Thomas Mattsson
8:45 – 9:30	Jovian planets and the hydrogen phase diagram	Ronald Redmer & Marcus Knudson
9:30 – 10:15	Physics of the Earth and Moon and experiments on Z	Stein Jacobsen
10:15 – 10:30	Break	Break
10:30 – 11:15	Future Challenges from Static High Pressure	Kanani Lee
11:15 – 12:00	Computational Approaches for Ultra-High Pressure Mineral Physics	Renate Wentzcovitch
12:00 – 1:15	Lunch	Lunch
1:15 – 1:45	The Z Astrophysical Plasma Properties collaboration	Greg Rochau
1:45 – 2:30	Atomic Kinetics of Photoionized Plasmas	Roberto Mancini
2:30 – 2:45	Break	Break
2:45 – 3:30	X-Ray line formation in radiation dominated astrophysical plasmas	Guillaume Loisel
3:30 – 4:15	Creating and Measuring White Dwarf Photospheres in a Terrestrial Laboratory	Ross Falcon
4:15 – 4:30	Break	Break
4:30 – 5:00	Stellar Opacity Modeling	Anil Pradhan
5:00 – 5:30	Measurements of iron plasma opacity at solar interior temperatures	Taisuke Nagayama

Wednesday July 23, 2014		
4 breakout rooms available until closing session starts at 3:00 pm		
7:30 – 8:30 Breakfast		
11:30 – 1:00 Lunch break		
8:30a to 3:00p	Individual breakout sessions in MagLIF/magnetized HED, Materials, Planetary, AstroPhysics	(Dan Sinars), (Thomas Mattsson), (Dylan Spaulding), (Don Winget and Jim Bailey)
3:00 to 5:00 pm	Summaries; user discussion; closing of workshop	Thomas Mattsson

MagLIF/magnetized HED

The plenary- and breakout sessions on MagLIF/magnetized HED science attracted a large and distinguished group of scientists with expertise in fusion, magneto hydrodynamics (MHD) theory, laser-plasma interaction, magneto Rayleigh-Taylor instabilities, and astrophysics applications. Students, postdocs, professors, and scientists from the National Laboratories took the stage in presenting leading-edge research in fusion. The excitement around the MagLIF concept was contagious and a number of research directions were presented and discussed over the three days.

There were six magnetized HED talks during Tuesday's plenary session. Dan Sinar (Sandia) gave an overview of Sandia's program in MagLIF. Dustin Froula (UR/LLE) discussed laser-plasma interactions, in particular the importance of filamentation at high laser intensities. Charles Seyler (Cornell) discussed extended MHD (XMHD) modeling and the effect of the Hall term in transport in HED plasmas like those in MagLIF. Paul Bellan (Caltech) presented fundamental science work on the stability of axial flows including the formation of jets. Y Y Lau (Michigan) discussed Rayleigh-Taylor instabilities with emphasis on the coupling between sausage, kink and MRT modes in imploding cylindrical liners. Finally, Jonathan Davies (UR/LLE) presented research on magnetized target fusion at LLE, describing small-scale MagLIF equivalent experiments that will be carried out on the Omega laser in FY15. The presentations were very well received and precipitated wide-ranging discussions.

Wednesday's breakout session was in the format of mini-seminars with intense discussions, there was frequently a barrage of questions after each speaker. Brian Appelbe (Imperial College) spoke on modeling the effect of theta magnetic fields on nTOF spectra. He gave a second talk on behalf of coworkers at Imperial College on the possible impacts of strength and materials on imploding liner dynamics.

Ron Gilgenbach (U Mich) discussed experiments on the 1 MA MAIZE pulsed power generator to study MRT and ET instabilities. Steve Slutz (Sandia) presented work on scaling of laser heating to targets for higher-current facilities. Matt Weis (graduate student at U Mich) presented work on detailed modeling of MRT instabilities. Frank Wessel and Hafiz Rahman presented work on their "Staged Z-Pinch" idea, which is also a magnetized imploding liner concept.

Paul Schmit (Sandia) discussed modeling of the "Knudsen effect", kinetic boundary effects on fusion, in a MagLIF context, concluding that the Knudsen effect is not really an issue for this system. Paul also discussed the use of nuclear measurements as a way of diagnosing the magnetization at stagnation. Matthias Geissel (Sandia) described laser-target chamber experiments in support of MagLIF, and discussed what the challenges look like going forward.

To summarize, the workshop exceeded our expectations in generating discussions regarding future research directions for MagLIF. Enthusiasm over recent results and optimism for the future dominated the discussions.

Material science

The plenary session Monday afternoon had four speakers: First, Yogi Gupta (WSU) presented an overview talk titled *Dynamic Compression of Solids using Planar Loading: Scientific Questions and Future Directions*, highlighting conceptual issues like the relationship between material strength/deformation and solid-solid phase transitions and the grand challenge of how to predict time-dependence of any material phenomena beyond elastic deformation. Yogi Gupta stressed the need for experimental development besides the large facilities: “Experiments are not events”.

The second talk was by David Reisman (Sandia) who spoke about the design of a new facility at Sandia, THOR. THOR will be a mid-scale pulsar aimed towards reaching 100 GPa in solids. The machine would operate using a number of switches kept independent via transit times through cables or delay lines. In discussions at the breakout session it was pointed out by Yogi Gupta that a capability to reach above 10 km/s flyer plates would add significantly to the impact of the machine.

The third talk was by Russ Olson (LANL) who discussed careful experiments studying RT instability growth depending on microstructure in a talk titled *Microstructural Influences on Dynamic Material Strength*. Russ Olson emphasized the effect on strength stemming from material processing and stressed that macroscopic deformation is often strongly affected by the material microstructure and that models need to parameterize or explicitly capture microstructure evolution.

The final talk was Bruce Remington (LLNL) who presented a talk titled *Probing novel regimes of HED science: plastic flow, lattice dynamics, and collisionless shocks*. With emphasis on the development of experimental platforms on laser facilities, exemplified by Rayleigh-Taylor strength experiments and Laue diffraction. Common to most development is the need for smaller scale facilities to develop the platforms. Access to Nova and Omega has been, and still is, a key component of developing experimental platforms for the NIF. “Our number of shot requests for Omega has not gone down since we began experiments on the NIF”.

While the material break-out session on Wednesday had two scheduled presentations: Jean-Paul Davis (Sandia) on design constraints for a mid-scale facility for dynamic materials experiments and Hojun Lim (Sandia) on Multi-scale modeling of plastic deformation in BCC metals, the emphasis was a detailed discussion on science needs in the intermediate pressure range. Consensus emerged around the following key capabilities: to probe areas of the phase diagram where significant questions remain it is necessary to reach 50% compression, which corresponds to around 100GPa for many common materials; diagnostics capabilities are crucial for making progress, excellent control of the load path is very important, for example to perform shock-ramp experiments. Finally, a reasonable repetition rate is very

important to allow for systematic investigation of the effect of microstructure on for example strength.

Planetary Science

Progress and future directions for planetary science on Z were the subjects of enthusiastic discussion and attracted invited speakers and new participants to the user meeting. A dedicated plenary session and full-day breakout session were devoted to presentations and discussions of contemporary challenges for both experiments and theory. Users are excited to approach new problems for which Z is uniquely capable and a number of directions for new research and collaborations were identified.

The Tuesday plenary session featured talks from the existing planetary science campaigns and two newly invited participants. Ronald Redmer (Rostock) and Marcus Knudsen (SNL) jointly presented recent progress on giant planet compositions and on exciting observations of the potential plasma phase transition (PPT) in hydrogen. These results will be relevant for interpreting upcoming observations from the Juno spacecraft which will arrive at Jupiter in 2016. Stein Jacobsen (Harvard) discussed outstanding issues surrounding the formation of the Moon, current experimental approaches for measuring vaporization and melting and the inadequacies of widely used equations of state for capturing the observed geochemical signatures of the Earth-Moon system. In addition, invited talks from two new participants highlighted the rich potential for new research directions. Kanani Lee (Yale) and Renata Wentzcovitch (U. Minnesota) discussed challenges in mineral physics at extreme conditions, which can potentially be addressed on Z, including complex melting and identification of phase changes associated with electronic spin transitions.

Wednesday's breakout session featured an extensive discussion on how to collaboratively address discrepancies between theory and experiment. Three short talks addressed current issues and measurements that would be valuable for validating calculated free energies, transport properties and phase relations. Two talks were devoted to bringing users up to speed with current and future diagnostic and experimental capabilities of the facility to assist with development of new ideas and future planning. Finally, a discussion was devoted to strengthening the user program, improving efficiency and maximizing the return on precious facility time for fundamental science.

The outcomes of both sessions were very positive. Outstanding directions for future research were identified, including further investigation of kinetics, transport properties and improved equations of state (particularly off-Hugoniot and low-temperature states). The users were in almost unanimous agreement that the

experimental platforms and load designs are well-tested, reliable and delivering outstanding results. However, it will be crucial to grow the diagnostic capabilities, particularly for temperature measurements and calibrated measurements of optical properties. There was tremendous enthusiasm in the group for the development of a smaller scale, more accessible pulsed power machine (THOR), which would be of tremendous use for a number of experiments in the several Mbar regime (which is particularly relevant for planetary science). Future directions were identified that would simultaneously address cutting-edge Earth science topics while also probing important discrepancies between observations and theory. These include more work on strongly correlated systems (such as FeO), the kinetics of solid-solid phase transitions under ramp compression and improved characterization of thermal states with in-situ, calibrated temperature measurements. The planetary science community is eager to push forward with these directions and discussions are underway for expanding collaborations and developing new ones pending future calls.

Astrophysics/ZAPP

In the Astrophysics section of the workshop, organized by Don Winget of the University of Texas at Austin and Jim Bailey of Sandia National Laboratories (SNL), the following were presented:

- 1) The Z Astrophysical Plasma Properties (ZAPP) collaboration, by Greg Rochau of SNL. This presentation described the experimental platform developed to simultaneously create and investigate multiple astrophysical plasmas. Important is that the absolute parameters (e.g. density and temperature), not only relevant dimensionless parameters, of the experimental and astrophysical plasmas are matched. As such this is a unique facility for astrophysical research, as demonstrated by results presented in the subsequent talks.
- 2) Atomic Kinetics of Photoionized Plasmas Break, by Roberto Mancini of the University of Nevada at Reno. Here experimental results were presented showing that computer codes currently available were not predicting the photo-ionized plasma parameters correctly. This discrepancy, if confirmed by further research, has important implications for our understanding of photo-ionized plasmas, both astrophysical and other. Initial results from collaborations with Los Alamos National Laboratory scientists suggest a route to a possible explanation.
- 3) X-Ray line formation in radiation dominated astrophysical plasmas, by Guillaume Loisel of SNL. Here first and preliminary results addressing the question of whether Resonant Auger Destruction (RAD) exists or not were presented. This process has been offered as an explanation for why certain X-ray lines are not observed from black hole accretions discs. However, the relevance of the RAD process to accretion discs has been questioned by Duane Liedahl of Lawrence Livermore National Laboratory. The preliminary results support Duane's contentions, although far more data is required before any definitive statement can

be made. When completed this work will inform our understanding of accretion discs, and the requirements of future space telescopes

4) Creating and Measuring White Dwarf Photospheres in a Terrestrial Laboratory Break, by Ross Falcon of the University of Texas at Austin. Ross recently successfully defended his doctoral thesis on the work he presented. He described using z-pinch dynamic hohlraum radiation to create macroscopic (Bratwurst-sized) hydrogen plasmas at white dwarf photosphere conditions. The first simultaneously measurements of multiple hydrogen Balmer lines at electron densities $>10^{17}$ particles/cc were presented, which provide constraints for measuring relative line shapes. There is important disagreement between experimental results and theoretical predictions. A result of this disagreement is that plasma conditions deduced from spectral fits to H-gamma differ from those deduced from H-beta: the deduced electron density is lower for H-gamma. This is intriguing and important, because in observed spectra from white dwarfs, higher-order hydrogen Balmer lines imply systematically lower surface gravity, which translates to lower electron densities. If the conditions inferred from H-beta are indeed more accurate than those inferred from H-gamma, as the experimental measurements suggest, then the mean mass of white dwarfs will increase. The implications are significant. For example, the cooling ages of white dwarfs increase and, since white dwarf ages constrain the ages of galaxies, the time after the Big Bang that galaxies formed decreases. A $\sim 15\%$ increase in the mean white dwarf mass could mean \sim half a billion years.

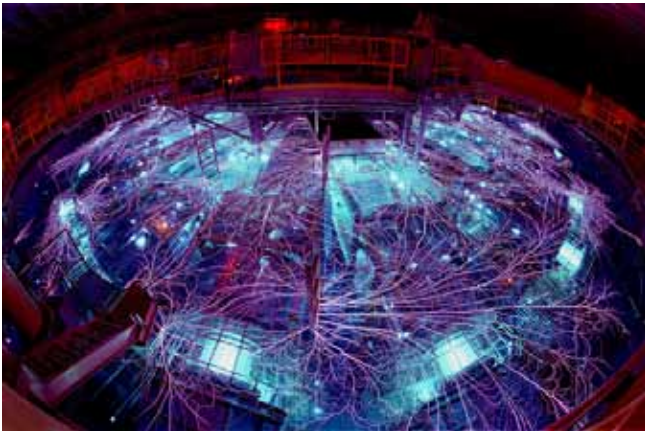
5) Stellar Opacity Modeling, by Anil Pradhan of the Ohio State University. Here the theoretical considerations and associated complications leading to improved modeling of opacities in regimes relevant to e.g. the sun's convection zone were explained. The results feed directly into the next presentation:

6) Measurements of iron plasma opacity at solar interior temperatures, by Taisuke Nagayama of SNL. Previous results using the Z facility to create plasmas similar to those in our sun suggest that we do not correctly model the opacity in the sun's convection zone. This important observation could, if upheld, explain a large discrepancy between the predictions of modern solar models and the results of helioseismology. In this talk careful and detailed experiments undertaken to understand and quantify errors and uncertainties were described. The conclusion is that the experimental data is indeed upheld under most stringent tests. Solar models must now take account of the new opacity data.

To summarize, every one of the astrophysical experimental projects utilizing the Z facility, and the project(s) informing those experiments, have produced unique, exciting, world-class, high-impact results.

Outbrief presentations

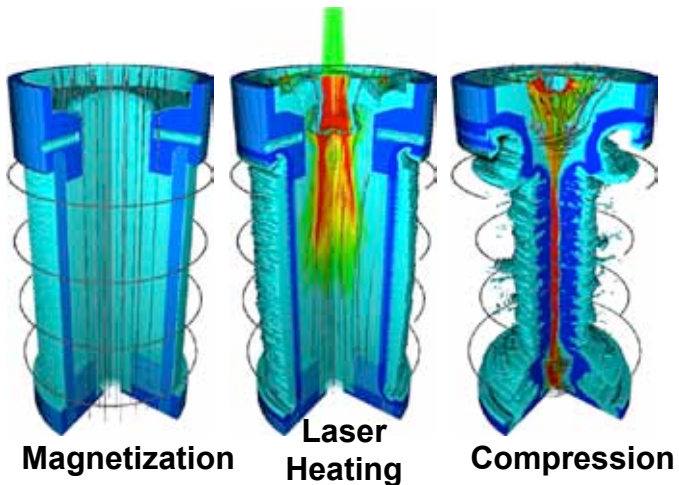
Exceptional service in the national interest



Fusion Breakout Session Summary

Daniel Sinars

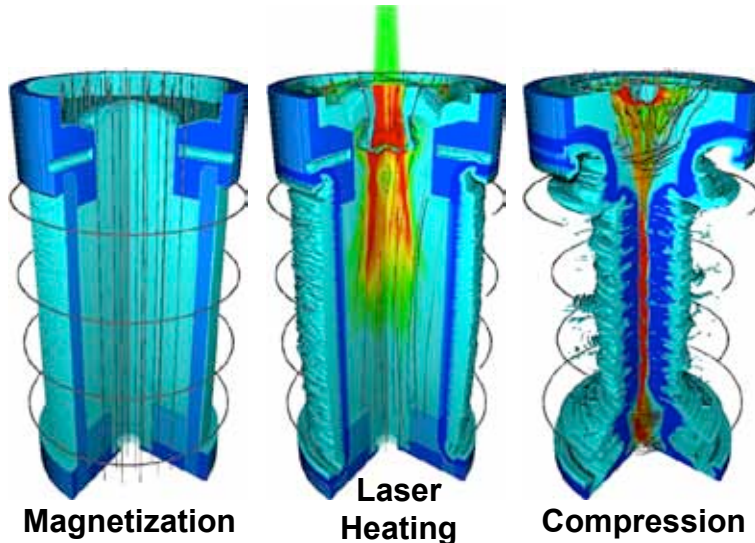
Sandia National Laboratories, Albuquerque, NM 87185 USA



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ZFSP2014, July 21-23, 2014

MagLIF, like all fusion approaches, touches on a wide and diverse range of physics with varying levels of understanding



■ Key target design elements

- Liner compression
- Magnetization
- Laser heating
- Fuel layering & burn

■ Key physics uncertainties

- Liner instabilities
 - Electro-thermal
 - Magneto-Rayleigh-Taylor
 - Deceleration RT
 - Impact of 3D fuel assembly
- Liner/fuel interactions & mix
- Laser-window and laser-fuel scattering, absorption, uniformity
- Suppression of electron heat transport in dense plasma by magnetic fields
- Magnetic flux compression
- Magnetized propagating burn

Experiments to address the key physics are underway on the Z pulsed power facility and the Z-Beamlet, Omega-EP, Omega lasers. Universities are also contributing to the science!

We heard from a wide variety of groups working on a diverse set of problems related to liner fusion



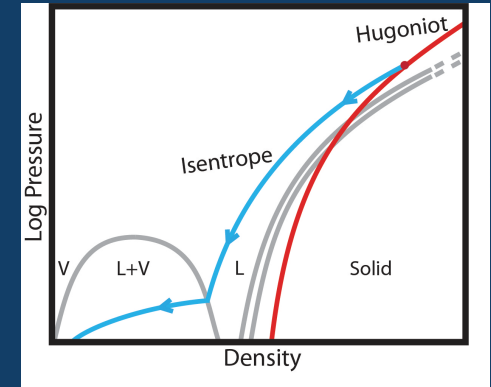
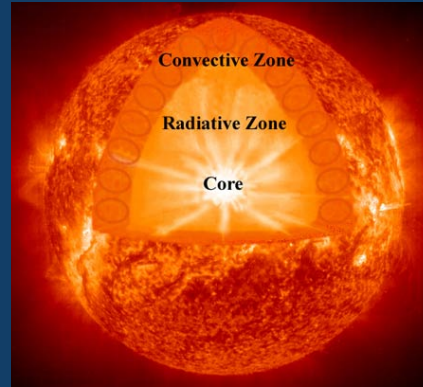
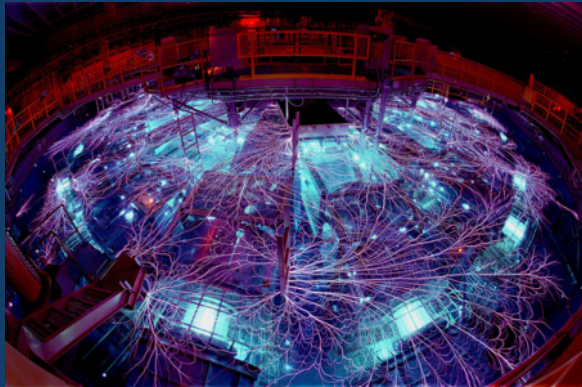
- Sandia: Integrated MagLIF experiments, Z-Beamlet laser experiments, effects of magnetization on neutron production, problems of scaling MagLIF to higher current facilities
- LLE & U. Rochester: Laser heating experiments, “MagLIF on Omega”
- Cornell, Caltech, U. Michigan: Liner/plasma dynamics experiments and modeling (especially MHD models of the magneto-Rayleigh-Taylor instability)
- Imperial College: Understanding the seed for the MRT instability (electro-thermal, material strength contributions?). Alternative heating schemes. Modeling to understand neutron time-of-flight signals from magnetized plasmas (including both B_z and B_θ)
- Rahman/Wessel: “Staged Z-pinch” as possible alternative to MagLIF (uses liner-generated shock as alternative preheating)
- Plus participation from additional groups during the workshop (UCSD, General Fusion, Los Alamos, Princeton *et al.*)

We at Sandia are very excited by our initial MagLIF results and are very thankful that we can draw on such a strong community to engage on the science



- Numerous interactions have occurred even before the workshop began! (e.g., Matthew Weis simulations from U. Michigan, Dustin Froula engaging on plans for upcoming Omega-EP experiments)
- During the past year we have received a lot of positive feedback from people across the fusion and z-pinch community about the quality of the science—this is driven by this community!
- Your continued support and high-quality work is essential if we are to make progress in these areas

Exceptional service in the national interest



Material break-out session outbrief

Thomas Mattsson

Manager, HEDP Theory

**Fundamental Science with Pulsed Power:
Research Opportunities and User Meeting
Albuquerque, NM July 20-23**



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Material break-out session – Majorca room 7/23

■ Presentations

- Thomas Mattsson – Background/overview
- Jean-Paul Davis – Using Thor
- Hojun Lim – Multiscale modeling of BCC strength
- Tom Ao – Present and future diagnostics on Z

■ Formulate priority research directions for Thor

- Wide and deep discussion on classes of materials and diagnostics
- Killer applications – form a line

■ Future of material research on Z

There are several benefits of an intermediate scale pulsed power facility

- Bruce Remington's observations
 - No reduction in shot requests for Omega with NIF online – key parts of development is still done on Omega
- Yogi Gupta's observations
 - Experiments are not events
 - Allow for experimental innovation and creativity,
- Platform development
 - Demonstrate feasibility for concepts, loads, diagnostics development
- Similar experiences on Z
 - Z pre-heat and MAPS developed on Veloce and STAR
 - Veloce lacks in capability to serve well in this role

There are several benefits of an intermediate scale pulsed power facility

- Materials are complex – the need for understanding the behavior of real materials
 - Systematic variations
 - Reproducibility
 - Set of load conditions and materials
- Trends, material properties
 - Rate dependence – three rates (200, 400, 800)
 - Grain size dependence (Hall-Petch) – three grains
 - Two grades of materials
 - Two shots each case + 10% contingency
 - $3 \times 3 \times 2 \times 2 \times 1.1 = 40$ shots – *not realistic on Z*

Key scientific drivers for a Thor class machine

- Real materials
 - Strength
 - Phase transitions
 - Strength across phase transitions
- Strength
 - Control loading & unloading
 - Fe, Zr, Ti, Li
 - Impurities, crystal direction, microstructure, bicrystal
 - In the first week we will have more data than all Z shots so far
 - Rapid turnaround, challenge models and understanding

100 GPa ramp
10 km/s Cu flyer
Diagnostics
Target beyond ambient

Key scientific drivers for a Thor class machine

- Phase transitions

- Rate dependence
- Nucleation
- Interpretation/analysis is key
- Many shots for reproducibility

100 GPa ramp
10 km/s Cu flyer
Diagnostics
Target beyond ambient

- Soft materials

- Foams, polymers, energetic materials
- Chemistry in dynamic compression

- Liquids

- Fundamental studies on solidification
- Rates, seeds, timescale, reversibility
- Metals and non-metals, many possibilities

Key scientific drivers for a Thor class machine

- Flyer plate Cu 10 km/s
 - A defining capability above and beyond two-stage guns
 - Couple with pre-heat
 - Geoscience relevant P/rho/T

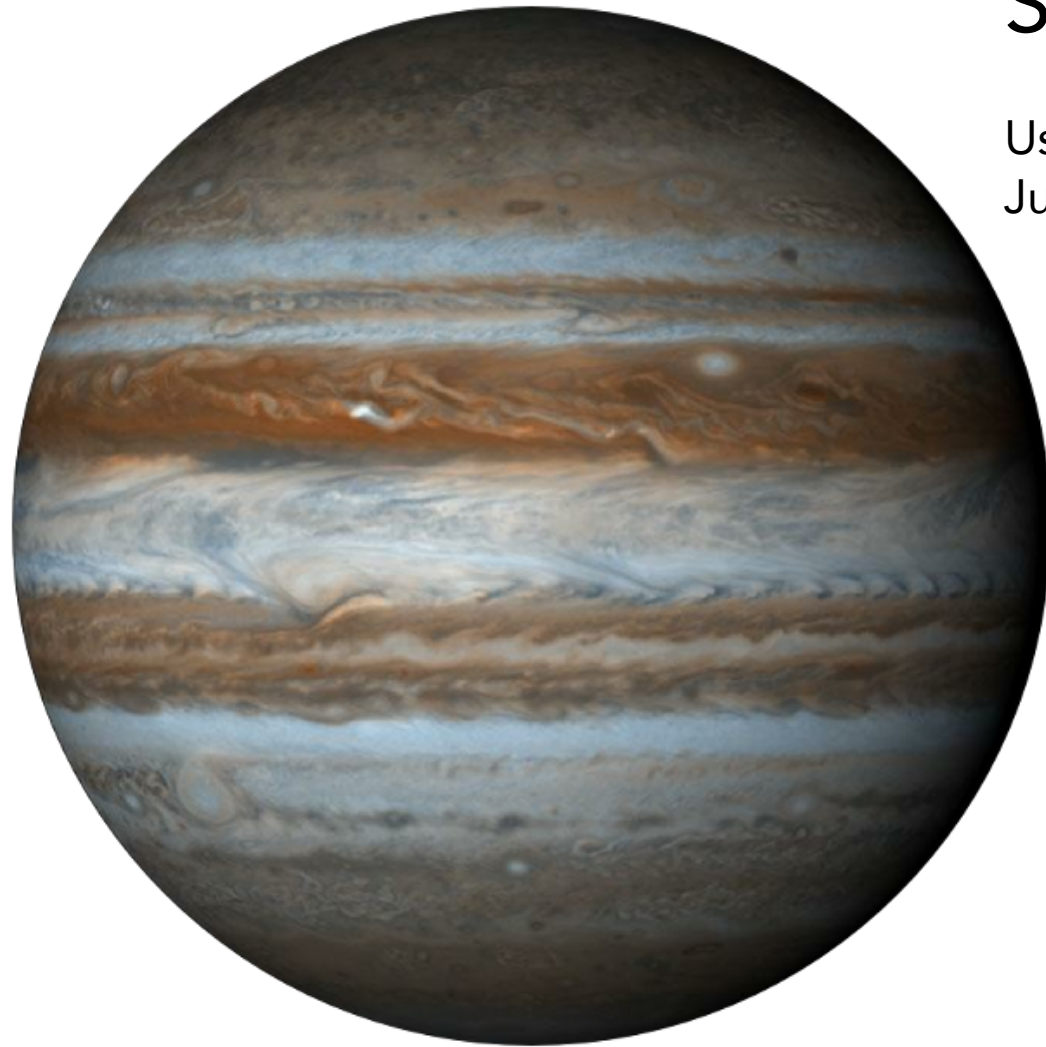
100 GPa ramp
10 km/s Cu flyer
Diagnostics
Target beyond ambient

- Cylindrical target
 - Not for pressure but for interplay between uniaxial compression and shear
 - Fundamental aspect of EOS/strength relationship 100 GPa an optimal regime

Genuine excitement
about the possibilities
of Thor

Outcomes from the Planetary Science Section

User Group Meeting Outbrief
July 23rd, 2014



Schedule of Talks in Planetary Science

Tuesday's Plenary Session

8:45 – 9:30	Ronald Redmer and Marcus Knudsen	Planetary Science Experiments on Z
9:30 – 10:15	Stein Jacobsen (Harvard)	The Origin of the Moon
10:15 – 10:30		Break
10:30 – 11:15	Kanani Lee (Yale U.)	Static to Dynamic: Experimental Constraints to Terrestrial Planetary Interiors
11:15 – 12:00	Renata Wentzcovitch (U. of Minn)	Computational Approaches for Ultra-High Pressure Mineral Physics
12:00 – 1:15		Lunch

Wednesday's Breakout Session

8:30– 9:00	Luke Shulenburger (SNL)	Prospects for Collaboration Between Theory and Experiment for Extreme Mineral Physics
9:00 – 9:30	Sebastien Hamel (LLNL)	Recent progress on the equation of state of carbon and silicon dioxide at extreme conditions
9:30-9:45	Ronald Redmer (Rostock)	Matter at Deep Interior Conditions of Giant Planets
9:45-10:00	<i>Group Discussion, Questions</i>	
10:00 – 10:15	Break	
10:15 – 10:45	Chris Seagle (SNL)	Experimental Capabilities and Challenges for Dynamic Material Properties on the Z Machine
10:45 – 11:15	Tom Ao (SNL)	Diagnostic Capabilities for Planetary Science Experiments on Z
11:15-11:30	<i>Group Discussion, Questions</i>	
11:30 – 1:00	Lunch	
1:00 – 1: 30	Dylan Spaulding (Harvard)	Recent Efforts to Strengthen and Grow User Programs (Summary and Discussion)
1:30 – 2:30	Discussion, Planning	Discussion on future experiments, theory and challenges, user needs and paths forward for planetary science

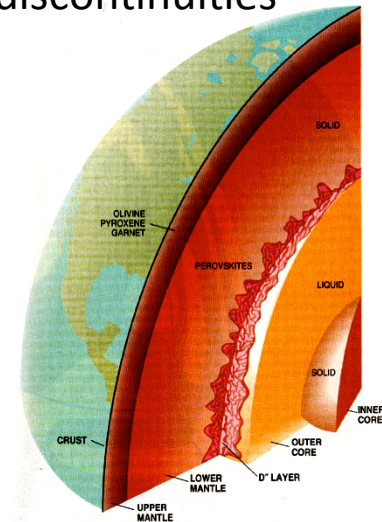
From Static to Dynamic, Shock to Ramp: Many Challenges Remain for the Planetary Science Community

Experimental Challenges:

- Platforms are relatively well-established and reliable. Diagnostics and sample availability/preparation are often limiting factors.
- Off-Hugoniot states are in high demand for planetary scientists
 - Vaporization vs. melt on release
 - Ramp Compression through solid-solid transitions (what about **temperature??**)
- Planetary models need to accurately address transport properties
 - 'Good' conductivity measurements
 - Better reconciliation of experimental estimates and calculations (DFT)
- Kinetics remain a potential source of uncertainty: Do ramps accurately sample solid-solid phase boundaries? What about hysteresis on loading/unloading? Vary strain rates on THOR, compare to other platforms to attack questions surrounding kinetics of transitions (Fe, SiO₂). Offline Z-Beamlet experiments could be conducted for this purpose.
- Controlled, calibrated visible/IR sources would be a great diagnostic addition and are critical for pyrometry calibration

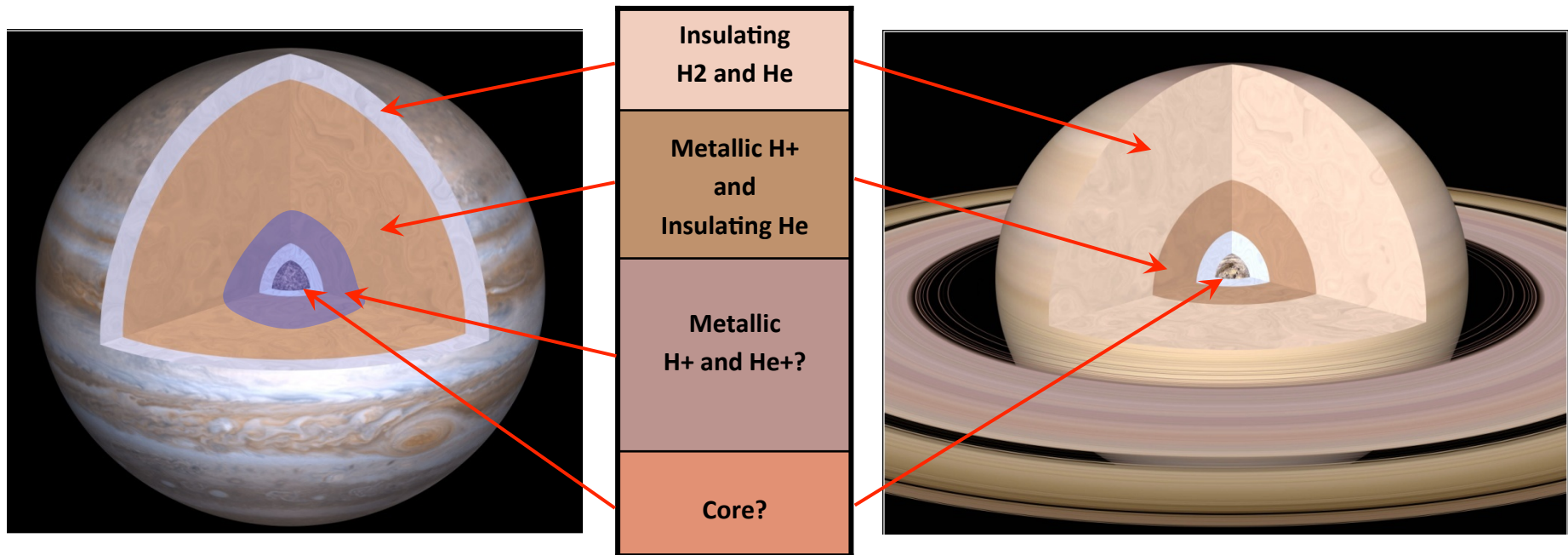
Terrestrial/Rocky Planet Compositions

- There is still little melt data in relevant regimes: Fe, (Mg, Fe)O, SiC, Bulk Silicate Earth compositions. What happens for solid-solutions, incongruent melting? Porous samples or preheated samples.
- Work towards shock-ramp experiments for crossing melt boundaries at higher pressure
- More detailed phase relations, EOS for Fe, (Mg, Fe)O, (Mg, Fe)SiO₃, (Mg, Fe)₂SiO₄, Fe₂O₃
- Release data on BSE compositions to observe melting and vaporization
- Subtleties in mineral physics? Spin transitions and related kinematic discontinuities (sound speed?)
- Sound Speed in liquid Fe (shock-ramp)
- EOS data for rocky cores in ~10-100 Mbar regime, 5-20 kK



Giant Planet Compositions

- H/He mixtures (shock-ramp to examine miscibility and metallization) and more accurate He hugoniot data.
- More accurate EOS (few points?) to distinguish between calculated models
- More 'ice' compositions (NH_3 , CH_4) needed for Uranus, Neptune
- Does GDP/Polyethylene convert to diamond in ICF/Giant Planet regimes?



Where Experiments can Help Validate Computation

- Free energies difficult to compute? Relates to understanding kinetics but large scale calculations are necessary.
- Band gap estimations tend to underestimate metallization (need conductivity measurements for validation)
- Better *thermal* EOS needed for validation (He, H₂O)?
- Data on strongly-correlated Fe-bearing materials (e.g. FeO)

Most Important User Tools/Needs

X-Ray Diffraction

Calibrated Temperature Measurements below ~ 5000 K

Ellipsometry (for conductivity estimates, optical properties)

Access to Z-Beamlet

Initial condition control (e.g. preheating and/or pre-compression)

Petawatt on Z – for preheat methods (proton heating or x-ray), x-ray diagnostics

Enhanced outside collaboration for sourcing targets (universities sometimes have expertise that can complement Z target fab for preparing/sourcing difficult targets)

Addressing Challenges to the User Program



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Dear Drs. Cook, Hommert and Goldstein:

On behalf of our membership, I wish to express our strongest support for the user programs collectively established at the National Ignition Facility (NIF) and the Z machine. We applaud the National Nuclear Security Administration's (NNSA) rescission of the cost-recovery initiative, which was temporarily emplaced in 2013, but we remain concerned that the user facility model cannot succeed without predictable, sustained support and that academic users continue to struggle with access to the facilities – NIF in particular. While the goal of devoting 15 percent of the NIF shot time to fundamental science has been widely promoted, only a handful of shots each year have been dedicated to basic research.

We do not wish to see other vital national security programs cut in order to accommodate users. On the contrary, we feel that a stronger commitment to integrating academic research would permit these facilities to fulfill their long-stated commitments to fundamental science while enhancing the laboratories' programmatic missions.

The best science is often a product of strong collaborations. By growing and sustaining a vibrant user community, NNSA will benefit from the skills and talents of many academic researchers whose contributions will directly support NNSA's national

security missions. Early results from academic users have already yielded several positive impacts on the national laboratories including:

- The development of experimental and analytical techniques immediately beneficial to the laboratories; data generated by users are invaluable for validation of mission-critical models and codes. Academic users have explored new regimes in nuclear, plasma and astrophysics, planetary science and condensed matter that directly complement the laboratory programs.
- Positive public visibility for the labs beyond their core missions. Livermore and Sandia scientists have been enthusiastically outspoken about the opportunities that they provide for collaboration, publication and interaction with the broader scientific community. Scholarly articles and popular press coverage reinforce the labs' broad expertise.
- A unique training pipeline for highly specialized young scientists. Building strong academic ties helps ensure the success of the national laboratory complex in the years to come and future US competitiveness in High Energy Density (HED) physics and related fields that depend strongly on these facilities.

The capacity for achievements in basic research across multiple disciplines is exceptional and the physics community is eager to share in realizing the full potential of these facilities if they are granted access. A renewed commitment to conducting fundamental science experiments will be critical for this to occur. We welcome the opportunity to further discuss how our membership can assist in growing and strengthening the user programs to the best advantage of the science and look forward to your response.

Sincerely,

Malcolm R. Beasley
President of the American Physical Society